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Spectral analyses of 16 DAO white dwarfs from the Sloan Digital Sky Survey

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Abstract. We present a spectral analysis of 16 DAO white dwarfs from the Sloan Digital Sky Survey Data Release 4. With our NLTE H+He model grid, we derived photospheric parameters for these objects. We compare our new results to literature values and divide the DAOs into two distinct groups: post-AGB and EHB progenitors.

1. Introduction

Even though most white dwarfs (WDs) have a simple atmospheric composition, either H- or He-dominated, some objects show mixed compositions, for example DAO WDs. These stars play an important role in the understanding of the evolution and nature of white dwarfs. Typical atmospheric parameters for DAOs are $T_{\rm eff} = 50 - 100$ kK, log[He/H] ~ -2 (by number), and a low surface gravity of $\log g \lesssim 7.5$ (cgs) (Bergeron et al. 1994; Napiwotzki 1999; Good et al. 2004).

The evolution towards DAO white dwarfs is still not satisfyingly understood. Because of the low surface gravity and low mass ($M < 0.5\ M_\odot$), derived for a large part of the analysed DAOs, a post-asymptotic giant branch (post-AGB) evolution of these objects seems to be rather unlikely since the mass is not high enough to ignite helium-shell burning on the horizontal branch (HB). Instead, an extended horizontal branch (EHB) history for these low-mass WDs is considered.

For those DAOs which are massive enough to start helium-shell burning on the HB, i.e. $M > 0.53\ M_\odot$, a post-AGB evolution is assumed. The star either evolves from a hydrogen-rich post-AGB star or a (hybrid) PG 1159 star. In the first case, one would expect a (sub-)solar helium abundance in the atmosphere of the DAO while the evolution from a hydrogen-deficient post-AGB object is realised by the decrease of mass loss and the resulting up-floating of hydrogen.

2. Models and fitting

We used NLTE synthetic spectra calculated with TMAP (Werner et al. 2003; Rauch & Deetjen 2003) from an extended atmosphere grid of H+He composed models with H/He abundance ratios of 10^9:1, 9:1, 8:2, 7:3, ..., 1:9, 1:10^9 by

Table 1. Atmospheric parameters of DAO white dwarfs. Masses are derived from evolution tracks of Wood (1995) assuming a thick hydrogen layer. Uncertainties are given by 1-σ statistical errors.

Name SDSS J	$T_{\rm eff}$ [kK]	$\log g$ (cgs)	log[He/H] (by numer)	M [$M_\odot$]
145606.73+491116.5[a]	90.4 ± 2.2	6.57 ± 0.07	-0.970 ± 0.001	0.44 ± 0.01
121743.14+623118.3	87.5 ± 1.8	6.80 ± 0.08	-0.929 ± 0.001	0.46 ± 0.01
160236.08+381950.6	87.1 ± 3.5	6.63 ± 0.08	-1.725 ± 0.004	0.43 ± 0.01
131925.93+531715.0	83.5 ± 2.9	6.57 ± 0.09	-0.742 ± 0.001	0.41 ± 0.01
034831.34+004616.3[b]	79.2 ± 1.1	6.99 ± 0.07	-1.982 ± 0.014	0.47 ± 0.01
120927.95−030206.3[c]	75.3 ± 2.6	6.78 ± 0.09	-1.725 ± 0.004	0.41 ± 0.02
153102.41+534900.6	74.8 ± 3.4	6.48 ± 0.10	-1.881 ± 0.009	0.34 ± 0.02
125029.51+505317.4	69.3 ± 5.8	6.56 ± 0.20	-1.177 ± 0.012	0.32 ± 0.05
082705.53+313008.3[d]	67.8 ± 0.7	6.84 ± 0.05	-1.881 ± 0.009	0.38 ± 0.01
163200.32−001928.3[e]	64.5 ± 4.5	7.86 ± 0.13	-1.079 ± 0.001	0.66 ± 0.05
101015.60+115711.3	59.5 ± 1.6	8.10 ± 0.13	-0.910 ± 0.004	0.76 ± 0.07
161441.99+370548.2	59.0 ± 0.6	7.76 ± 0.07	-1.982 ± 0.014	0.61 ± 0.03
135356.89−025630.4	50.7 ± 1.3	7.86 ± 0.06	-1.467 ± 0.001	0.63 ± 0.03
081618.80+034234.2	50.0 ± 0.5	7.00 ± 0.09	-0.970 ± 0.001	0.36 ± 0.03
235137.25+010844.1	50.0 ± 0.3	7.76 ± 0.06	-0.294 ± 0.001	0.59 ± 0.02
170508.82+212019.3	50.0 ± 0.1	8.04 ± 0.04	-1.982 ± 0.014	0.71 ± 0.02

[a]: PG 1454+494: sd (Kilkenny et al. 1988); [b]: KUV 03459+0037: sdB (Wegner & Boley 1993); [c]: PG 1206−028: sdO(B) (Kilkenny et al. 1988); [d]: TON 320: DAO (Bergeron et al. 1994); [e]: WD 1629−002: DAO (Krzesiński et al. 2004)

mass. Furthermore, we interpolated models with H/He abundance ratios of 9.5:0.5, 8.5:1.5, and 7.5:2.5 by mass. The model grid ranges from 50 − 190 kK and $\log g$ is in the region from 5.0 − 9.0. The emergent fluxes were calculated using Stark broadening tables of Lemke (1997), Barnard et al. (1974), and Schöning & Butler (1989) for H I, He I, and He II line broadening, respectively. The model atmospheres were calculated for a homogeneous composition which is appropriate for DAOs as shown by Bergeron et al. (1994).

We determined best-fit models using our automated χ^2-fitting routines (Hügelmeyer 2006). We fitted the spectrum in the regions marked in Fig. 1 and performed an interpolation between χ^2-values to refine photospheric parameters. Napiwotzki (1999) reports that the high Balmer lines are the most solid temperature indicator. Our fitting yields best-fit models that reproduce Hγ and Hδ most accurately. Three DAOs hit the lower $T_{\rm eff}$ limit of our model grid. In these cases one-sided errors are given. The SDSS spectra together with best-fit models are shown in Fig. 1.

3. Results and discussion

The atmospheric parameters derived from our analysis are shown in Table 1 and, compared to literature values from Bergeron et al. (1994), Napiwotzki (1999), and Good et al. (2004), in the plots of Fig. 2. It suggests a division of the DAOs into two distinct groups: all stars represented by grey symbols have $\log g > 7.5$ and a mass $> 0.5\ M_\odot$, which is sufficient for the progenitor HB star to start

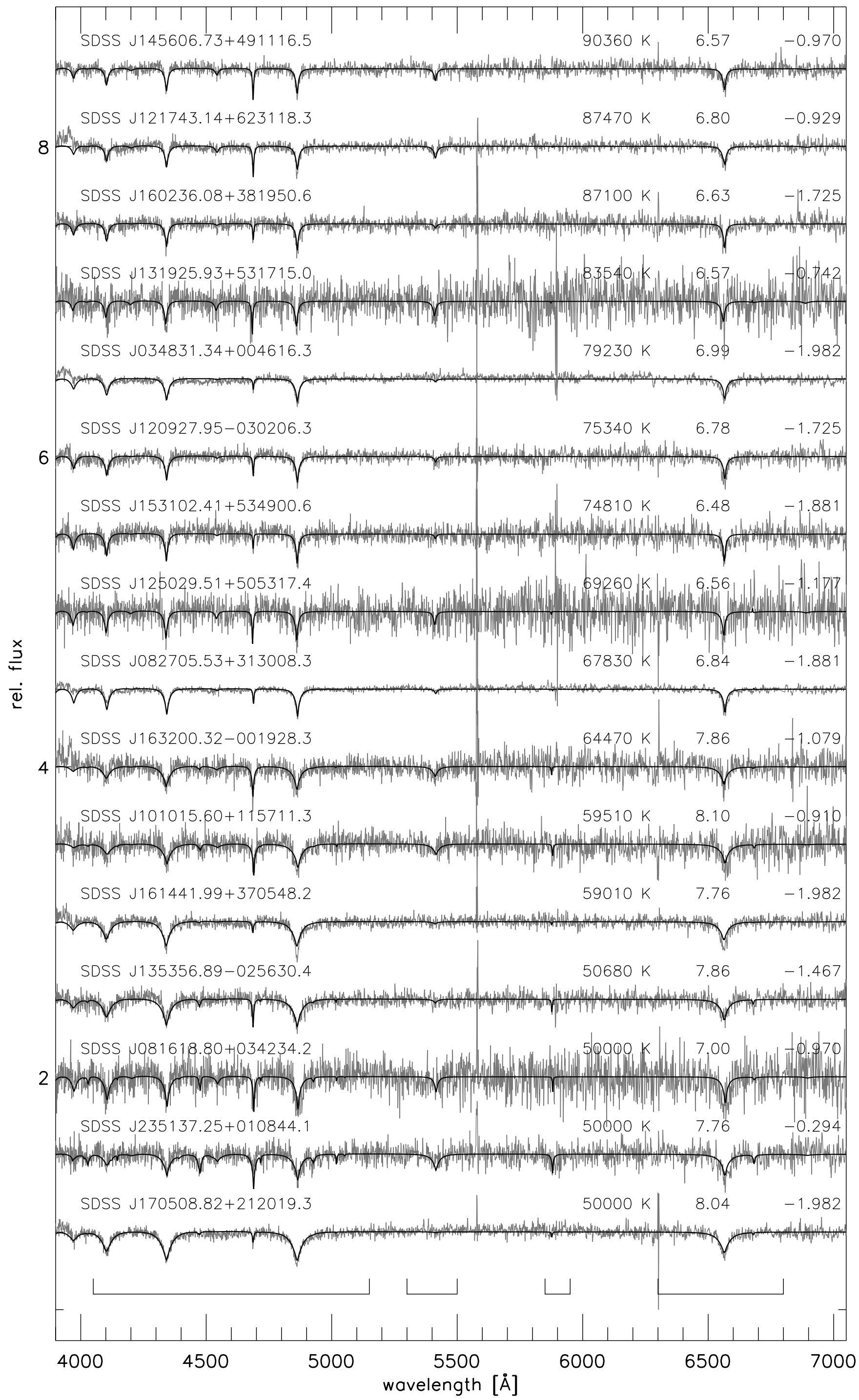

Figure 1. SDSS spectra (grey lines) and best-fit models (black lines) of DAO white dwarfs. The labels denote SDSS name, $T_{\rm eff}$, $\log g$, and log[He/H]. The marks at the bottom show regions where fitting has been performed.

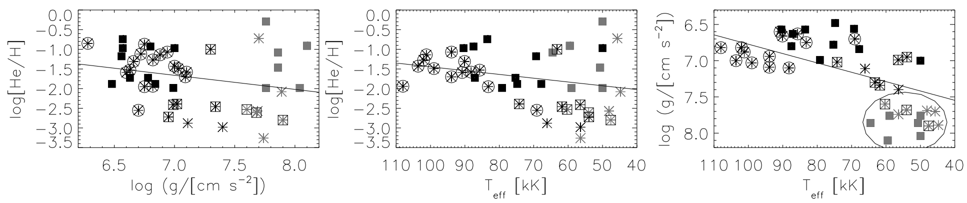

Figure 2. Photospheric parameters for known DAO white dwarfs. Literature values are taken from Bergeron et al. (1994, asterisks), Napiwotzki (1999, circled asterisks), and Good et al. (2004, squared asterisks) and this work (filled squares). The line is a linear fit through all data points.

He-shell burning and ascend the AGB. Therefore, these stars should have had a post-AGB history. The black symbols in Fig. 2 are less compact objects among which we find the H-rich CSPNs from Napiwotzki (1999) ($M > 0.5\ M_\odot$ except for GD 561 or Sh 2-174 with $M = 0.43\ M_\odot$) and the less massive DAOs which we believe evolved directly from the EHB or in a binary evolution directly from the RGB (Driebe et al. 1998). This division in post-AGB and EHB progenitors is further underlined by the fact that the high gravity objects also have a tendency to be more He-rich than the other DAOs which implies that the former ones originate from He-rich post-AGB stars such as (hybrid) PG 1159 stars.

We have excluded the possibility that the mixed hydrogen and helium spectra originate from double-degenerate binary systems consisting of e.g. a DA and a DO white dwarf. Radial velocity measurements are necessary to check for binarity of the SDSS DAO white dwarfs of this analysis.

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